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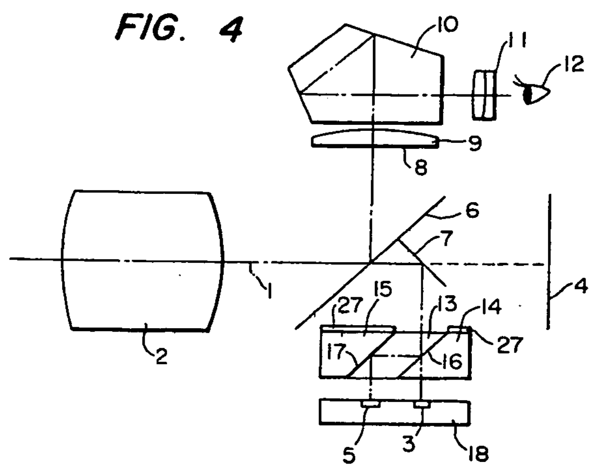
Harum Aoki.
(74) Agents
Marks & Clerk

(54) Focus detecting system

(57) A contrast function $\Sigma | x_i - x_{i+1} |$ of a scene to be photographed is evaluated both in front of, and behind, the effective plane of the film by using two arrays 3, 5 of detectors, and the lens system is adjusted to minimise the difference in the two contrast values. Additional pairs of detector arrays at greater distances than the pair 3, 5, can be used to effect coarse focussing.

FIG. 4



The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

FIG. 1

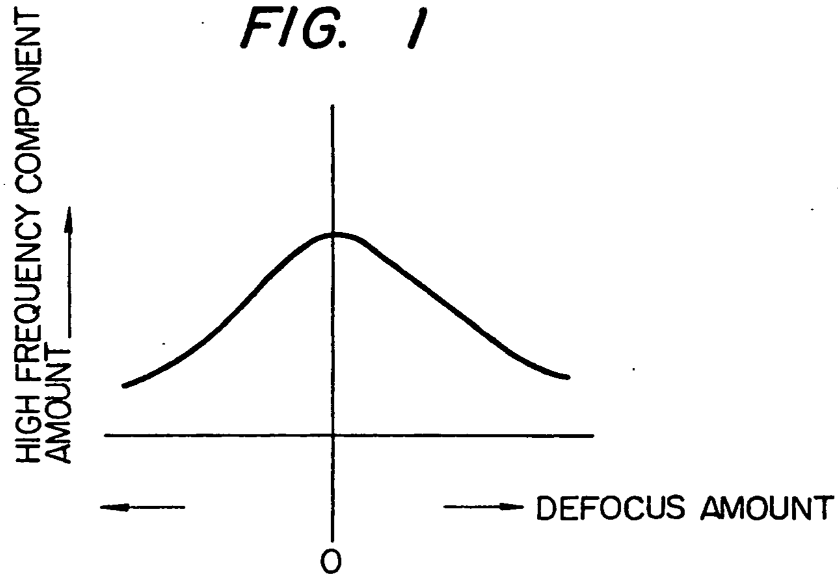


FIG. 2

FIG. 3

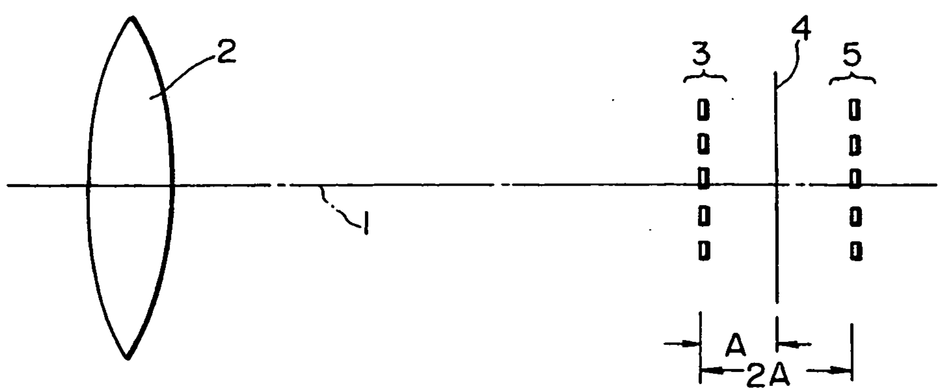


FIG. 4

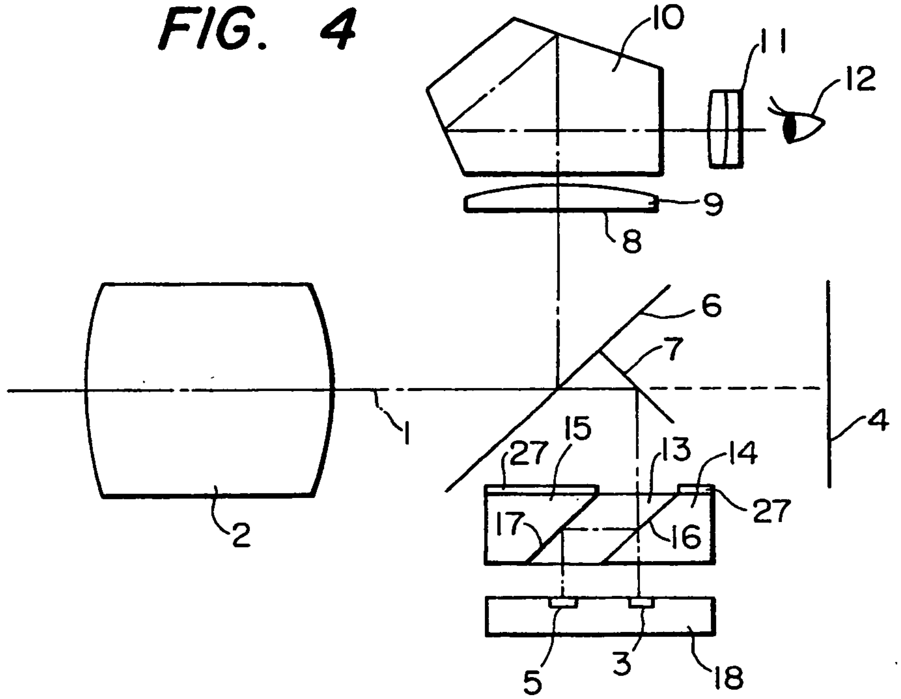

10
11
12
9
8
6
7
1
4
2
15
27
13
14
27
17
16
5
3
18

FIG. 5

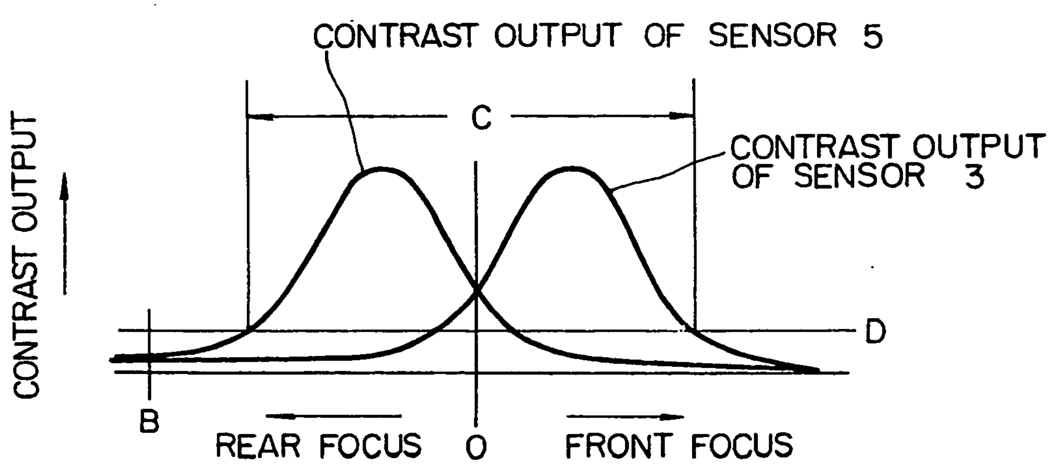

CONTRAST OUTPUT OF SENSOR 5
C
CONTRAST OUTPUT OF SENSOR 3
CONTRAST OUTPUT
D
B
REAR FOCUS
O
FRONT FOCUS

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FIG. 6

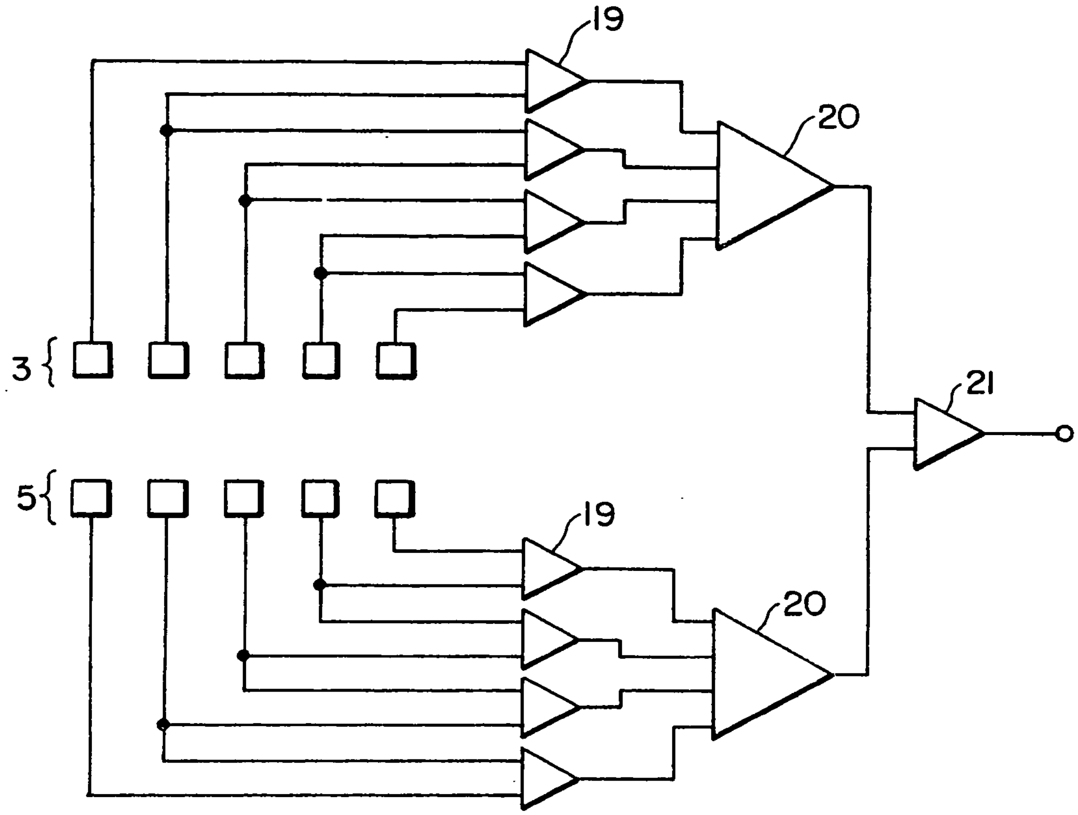


FIG. 7

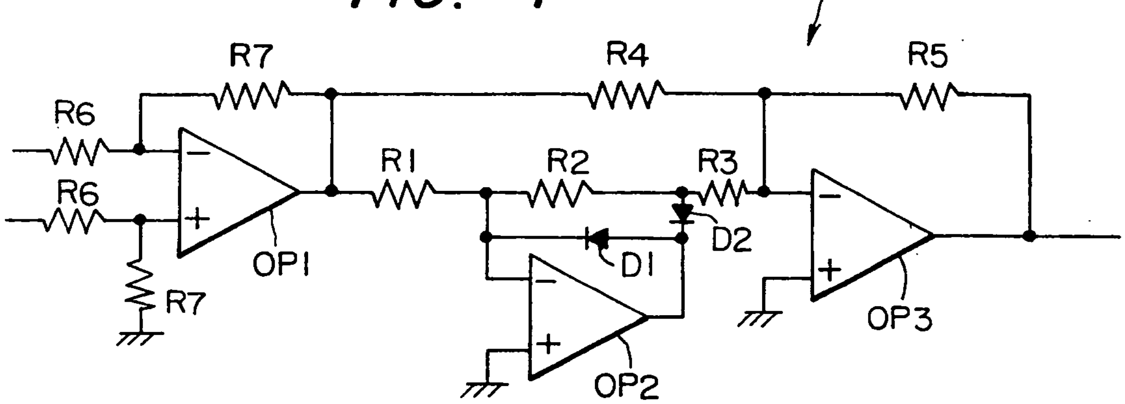


FIG. 8

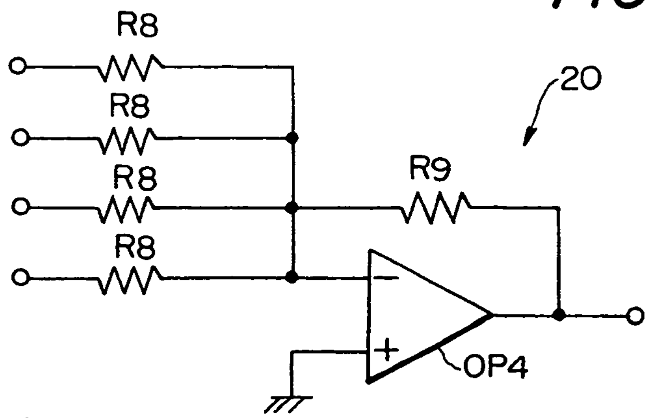


FIG. 9

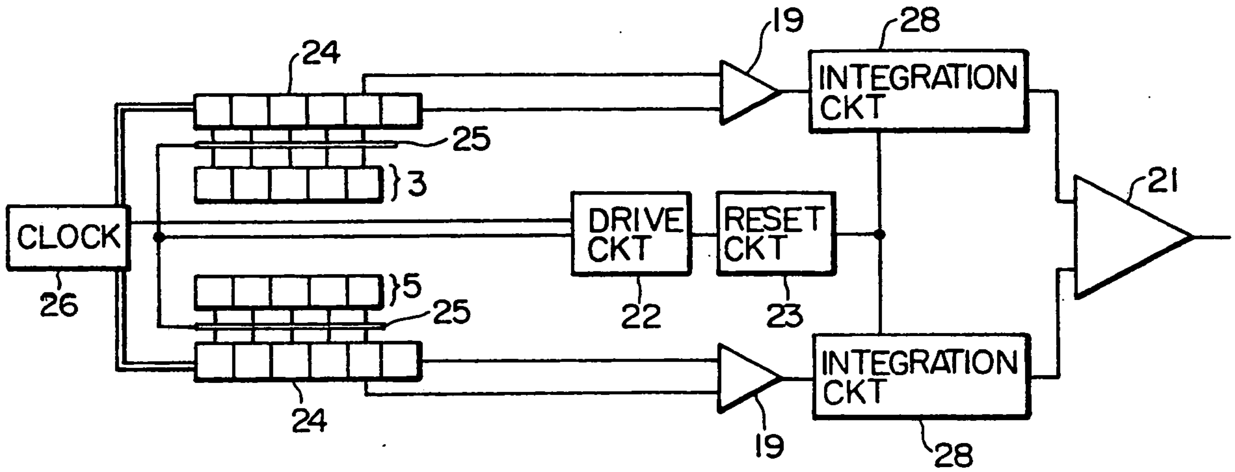
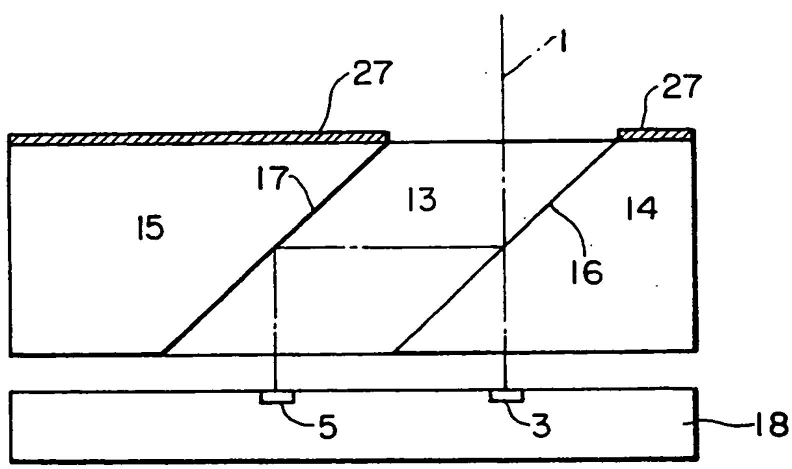

CLOCK
26
24
25
3
5
25
24
DRIVE CKT
22
RESET CKT
23
19
19
INTEGRATION CKT
28
INTEGRATION CKT
28
21

FIG. 10


1
27
27
17
13
14
15
16
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3
18

FIG. 11

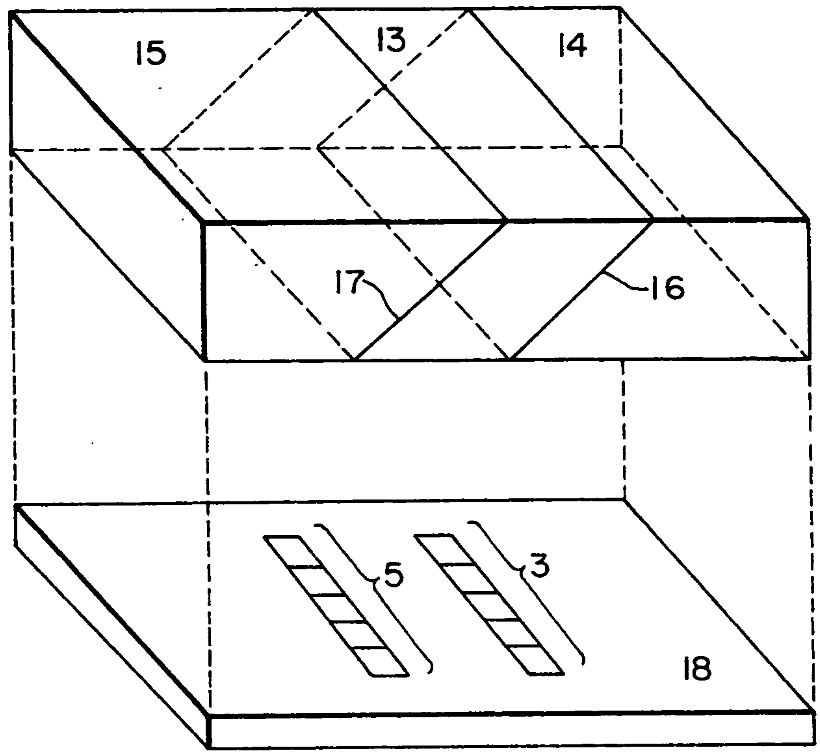

FIG. 12

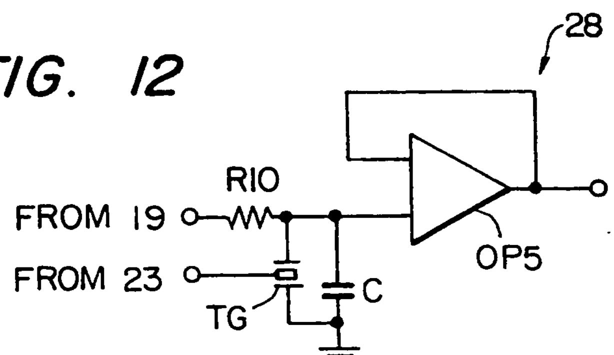

FIG. 13

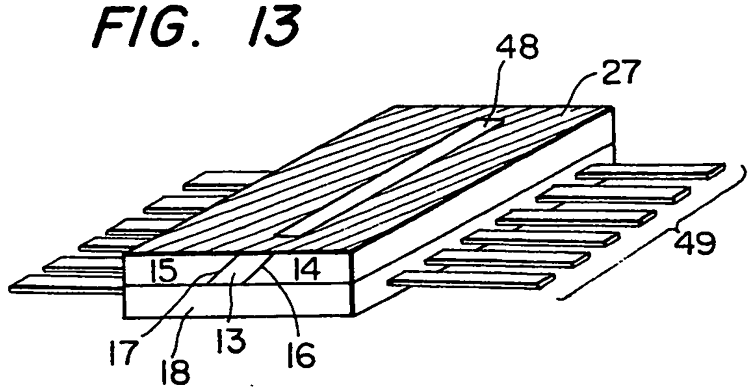

FIG. 14

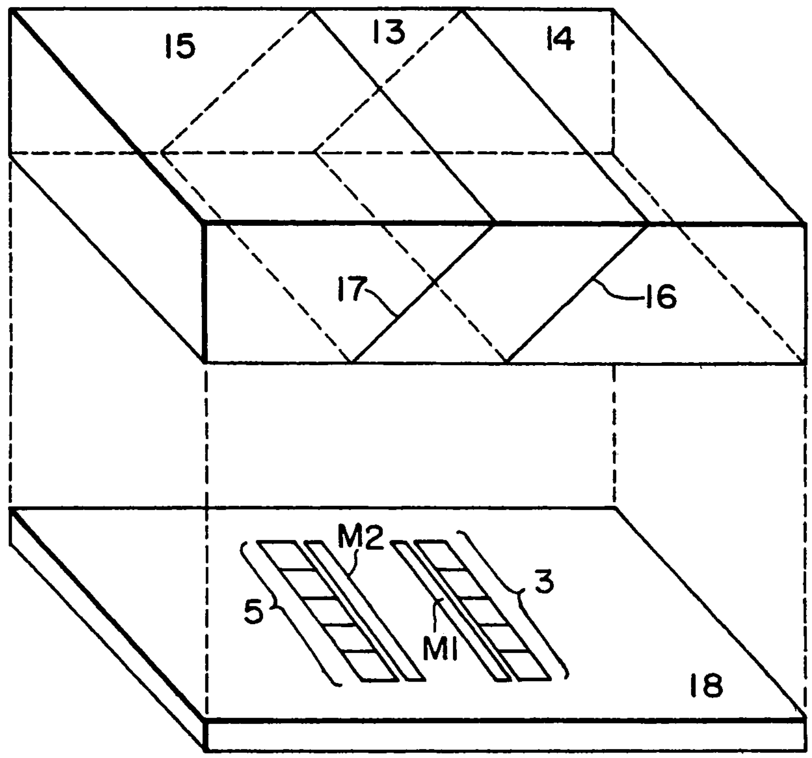
15
13
14
17
16
M2
5
3
M1
18

FIG. 15

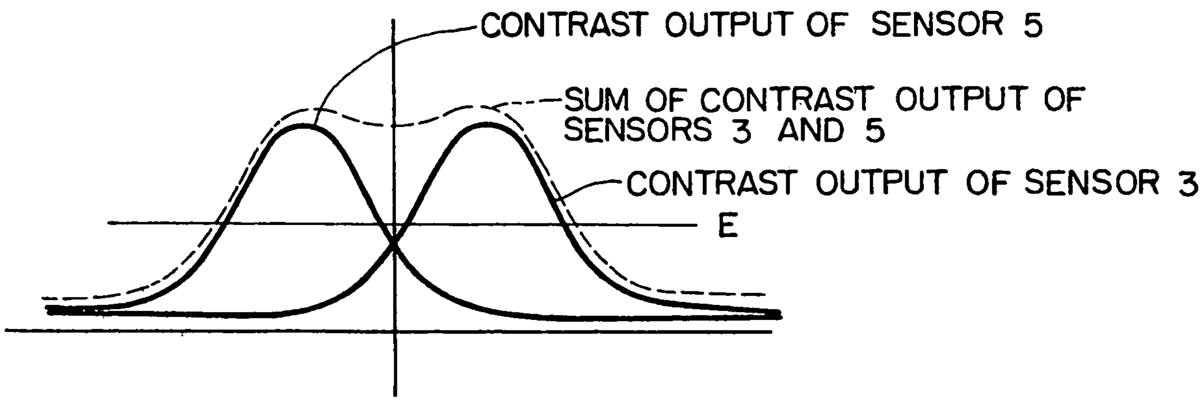
CONTRAST OUTPUT OF SENSOR 5
SUM OF CONTRAST OUTPUT OF SENSORS 3 AND 5
CONTRAST OUTPUT OF SENSOR 3
E

FIG. 16

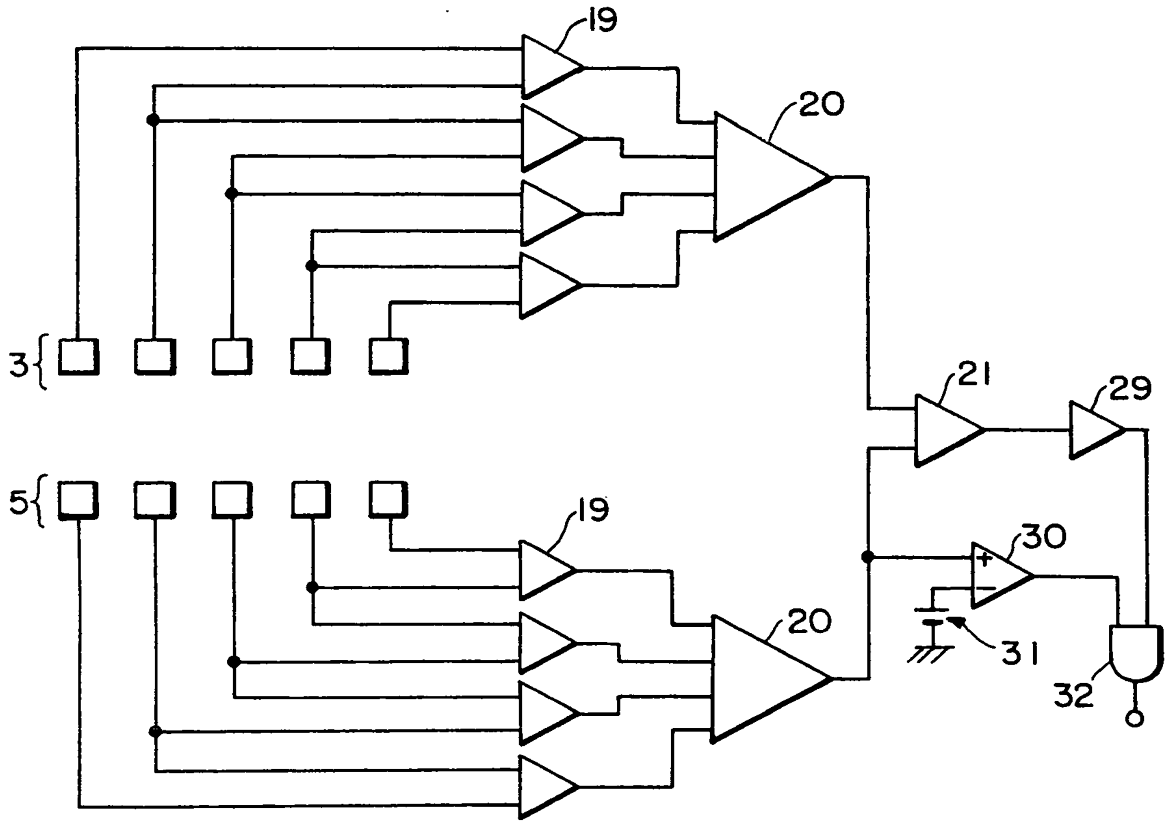

FIG. 17

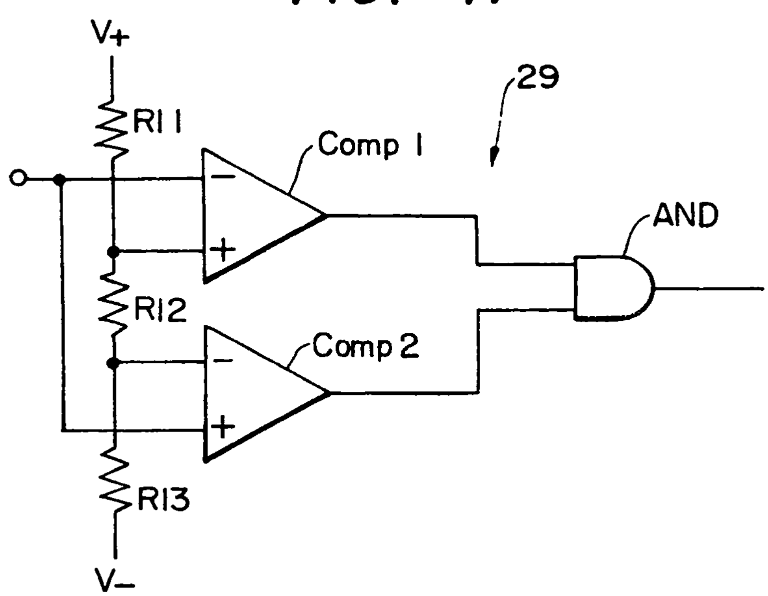

FIG. 18

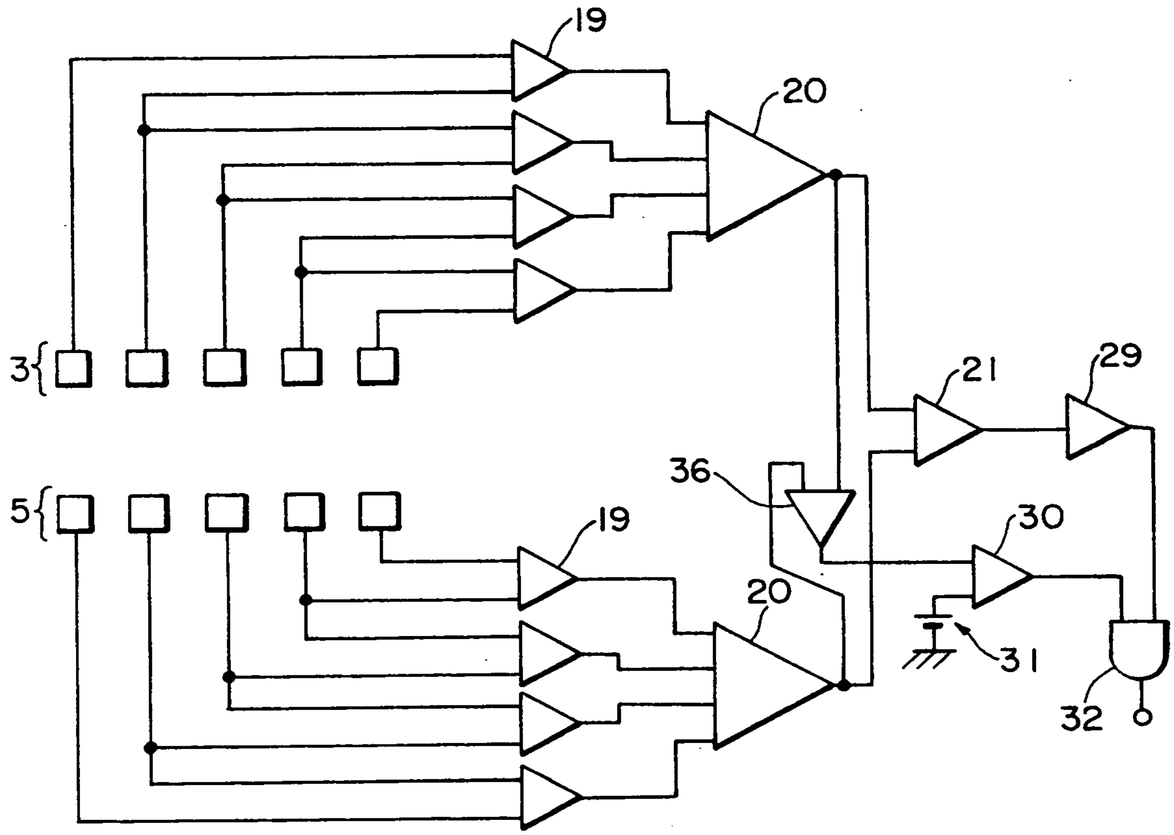

FIG. 19

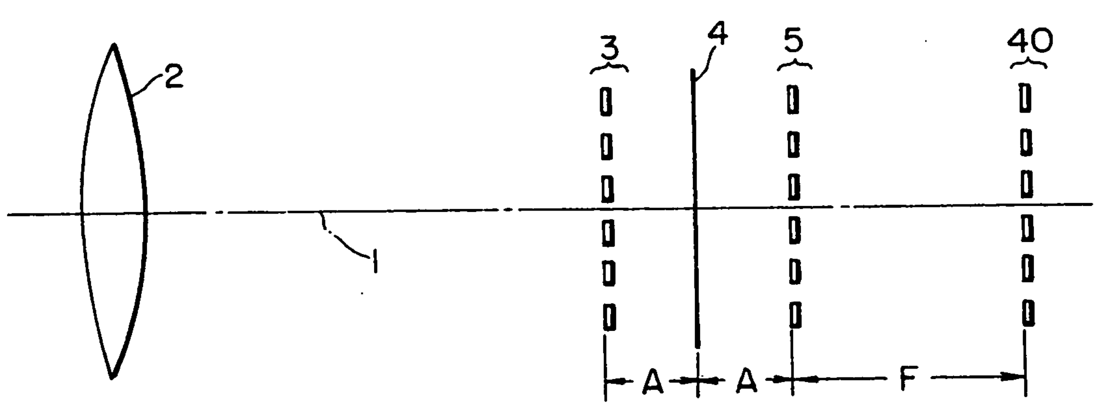

FIG. 20

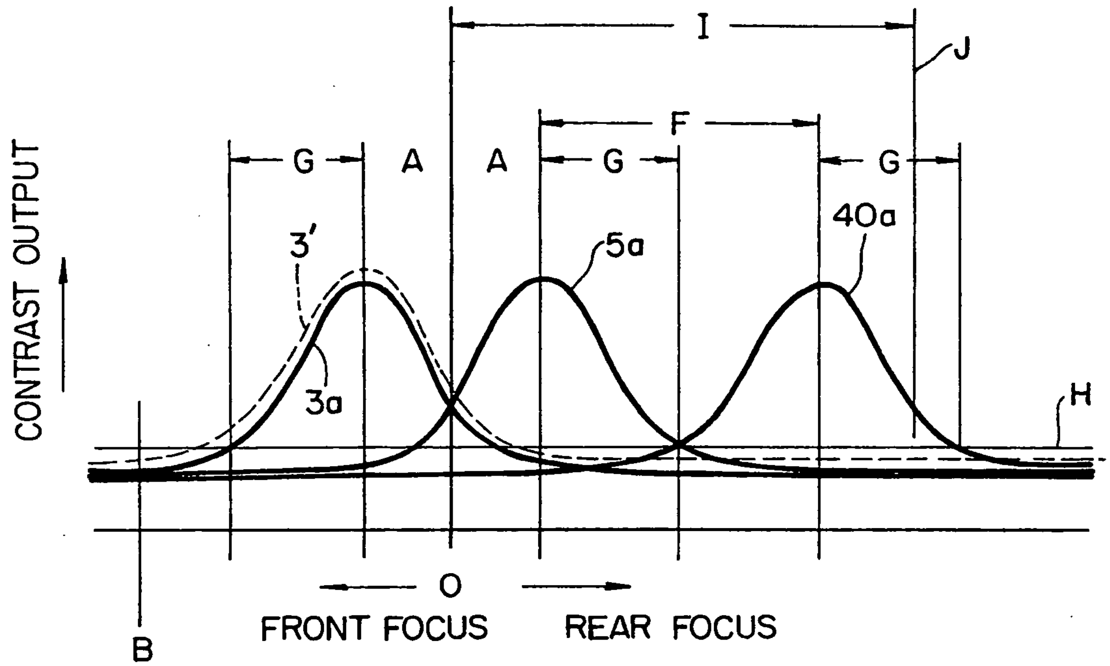

FIG. 21

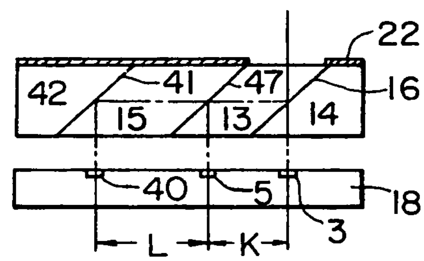

FIG. 22

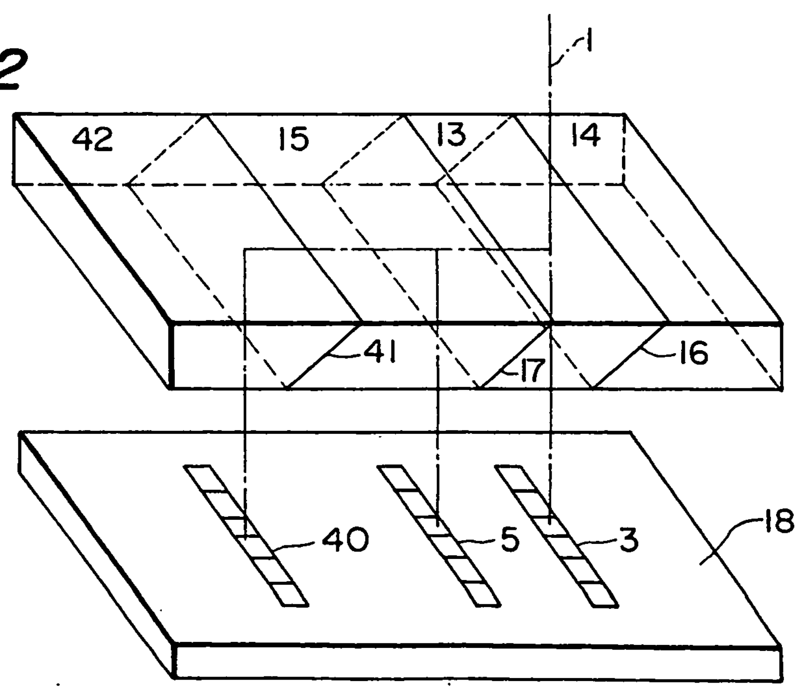

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FIG. 23

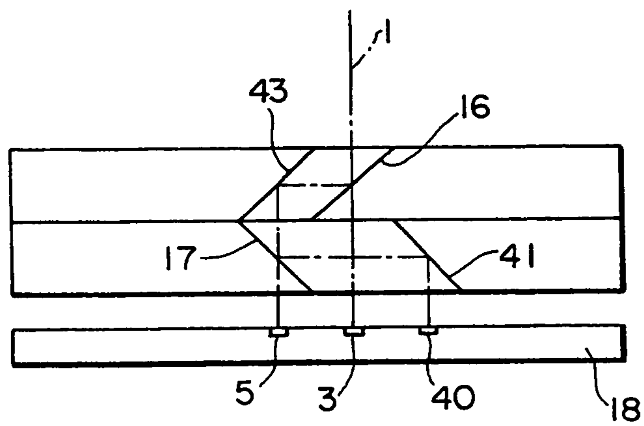


FIG. 24

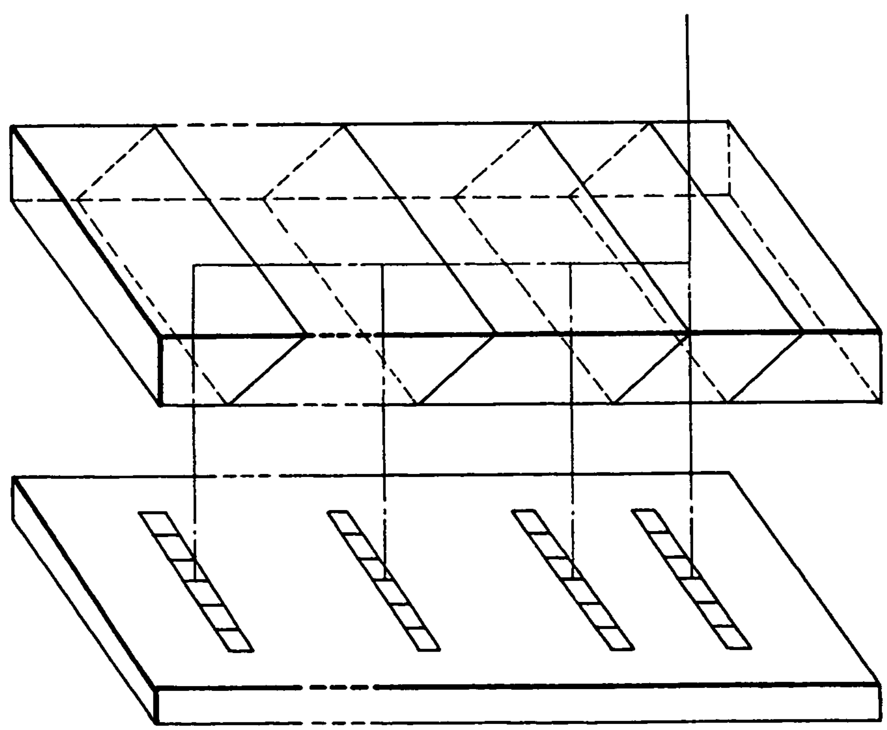
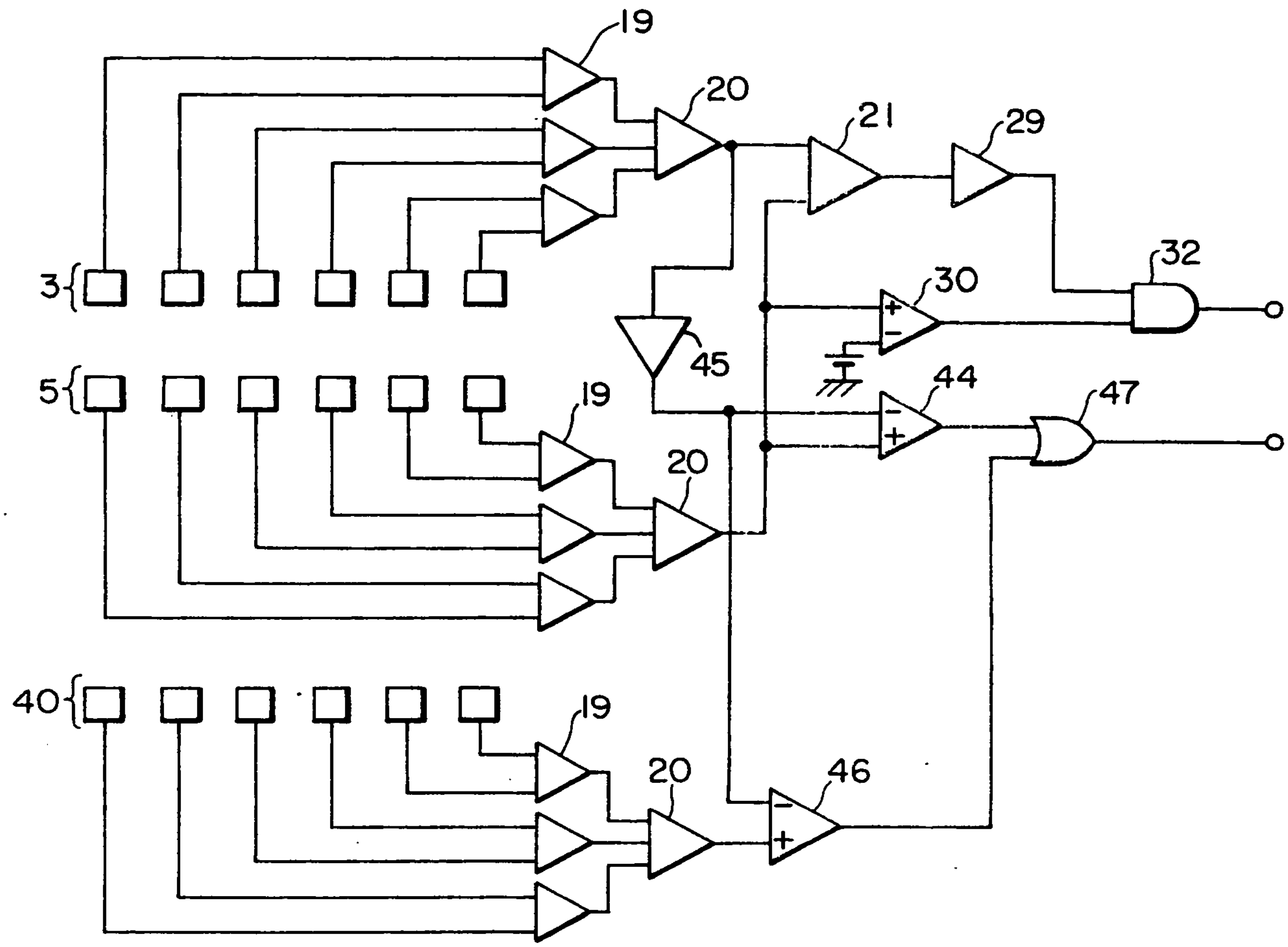


FIG. 25



19
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32
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45
44
47
5
19
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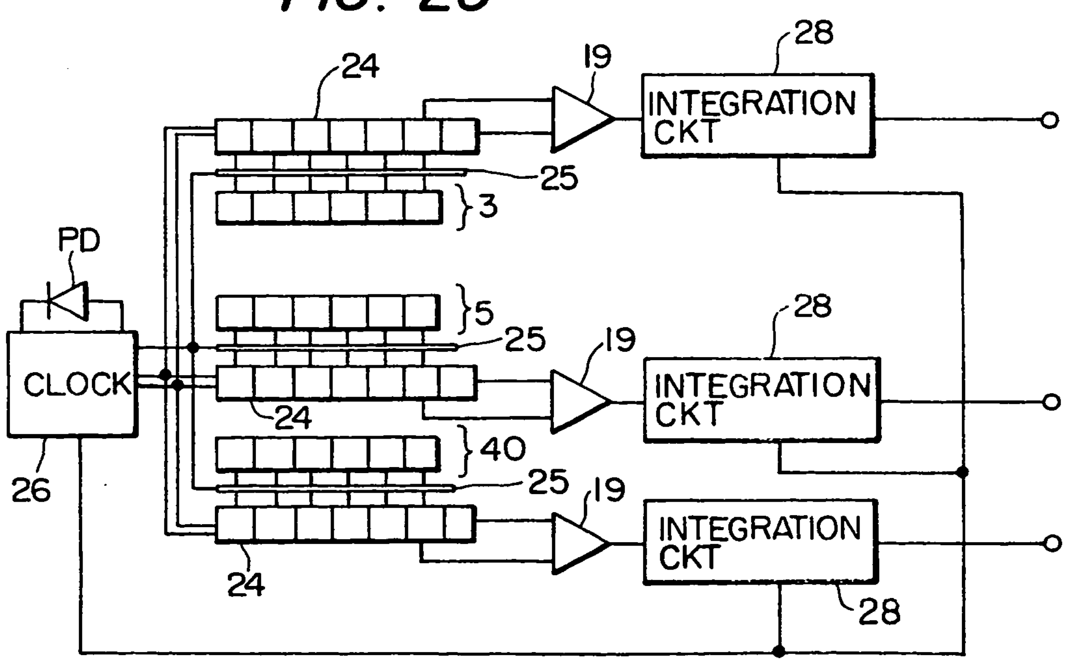
40
19
20
46

FIG. 26



28
24
19
INTEGRATION CKT
25
3
PD
5
25
28
19
CLOCK
INTEGRATION CKT
24
40
25
19
26
INTEGRATION CKT
24
28

SPECIFICATION

Camera focus detecting device

The present invention relates to a focus detecting device for cameras, and, particularly, the invention relates to a device for detecting the contrast of an image formed by a photographing lens to detect focus.

It has been known in the art that the relation between the amount of defocus, specifically, the distance between the plane of an image at the point of focus and the plane of an image at the point of defocus and the amount of high spatial frequency components of the spatial frequency spectrum of an image can be represented by a symmetrical characteristic curve having a single peak as shown in Figure 1. Accordingly, as the amount of defocus increases the amount of high spatial frequency component decreases.

A technique for detecting the amount of high spatial frequency components has been known in which an array of light receiving elements having uniform photoelectric characteristics and arranged along a straight line is disposed in a plane parallel to the plane of an image. In this arrangement, the amount of high spatial frequency components is detected from the sum of the differences in output between adjacent light receiving elements. For convenience for the description, which follows the amount of high spatial frequency components thus determined will be referred to hereinafter as "a contrast output".

According to the present invention there is provided a focus detecting device for a camera wherein the position of correct focus is automatically detected and the camera lens positioned accordingly comprising at least two groups of light receiving elements disposed in two parallel planes along an optical axis of a photographing lens of the camera with at least one of the planes laying on each side of a plane optically equivalent to a film surface;
a circuit for analyzing outputs of the groups of light receiving elements for detecting the degree of focus in the planes in which the groups of light receiving elements lie and producing contrast outputs; and a processing cir cuit coupled to receive outputs from said analyzing circuit for producing a signal indicative of the lens being at a correct position of focus when the contrast outputs from a predetermined two of the groups of light receiving elements are equal to each other.

The present invention will now be described in more detail, by way of example, with reference to the accompanying drawings in which:-

Figure 1 is a graph showing the amount of high spatial frequency components vs. the state of focus in the plane of an image.

Figure 2 is a diagram showing an array of sensors used in a device of the invention.

Figure 3 is a diagram used for a description of the principle of operation of a focus detecting device of the present invention.

Figure 4 is a cross sectional view of a single-lens reflex camera incorporating a focus detecting device according to the invention.

Figure 5 is a graph showing the sensor output vs. focus position utilized in explaining the operation of a device of the invention.

Figure 6 is a circuit diagram showing a first example of a processing circuit for processing the outputs of the sensors.

Figure 7 is a circuit diagram of a comparison circuit 19 as used in the circuit of Figure 6, for determining the absolute value of the difference between the sensor outputs.

Figure 8 is a circuit diagram of an adder circuit 20 as used in the circuit of Figure 6.

Figure 9 is a circuit diagram showing a first example of a signal processing circuit employing an analog charge transfer element.

Figure 10 is an enlarged view showing the sensors and glass blocks of the embodiment of Figure 4 in more detail.

Figure 11 is a perspective view of the glass blocks and sensors of Figure 10.

Figure 12 shows a circuit diagram of an integrated circuit 28 as used in the circuit of Figure 9.

Figure 13 is a perspective view showing an example of an embodiment of the invention formed in a flat package utilizing integrated circuit techniques.

Figure 14 shows another embodiment of the sensors and glass blocks according to the invention.

Figure 15 are graphs showing sensor output vs. focus position utilized in explaining the operation of a device of the invention.

Figure 16 is a circuit diagram showing a second example of processing circuit for processing the outputs of the sensors.

Figure 17 is a circuit diagram of a window comparator 29 as used in the circuit of Figure 16.

Figure 18 is a circuit diagram showing a third example of processing circuit for processing the outputs of the sensors.

Figure 19 is a diagram used for a description of the principles of operation of another embodiment of a focus detecting device of the invention.

Figure 20 is a graph indicating the contrast outputs of the sensors in the embodiment of Figure 19 for various lens positions.

Figure 21 is a sectional view showing an arrangement of three sensors and a glass block assemply as may be used with the embodiment of Figure 19.

Figure 22 is a perspective view of the arrangement of Figure 21.

Figure 23 shows another example of a unit including glass blocks and three sensors.

Figure 24 is a perspective view of an arrangement of four sensors and a glass block assembly.

Figure 25 is a circuit diagram showing a fourth example of processing circuit for processing the outputs of the sensors of Figure 19.

Figure 26 is a circuit diagram showing a second example of a signal processing circuit employing an analog charge transfer element.

The principle of the present invention will first be described with reference to Figure 3 in which reference numeral 1 designates the optical axis of a photographing lens 2; 4, the surface of a film; and 3

and 5, sensors. The sensor 3 is spaced by a distance A toward the lens 2 from the film surface 4 while the sensor 5 is spaced by the same distance A in the opposite direction from the film surface 4. These components are positioned such that during exposure the sensor 3, the film surface 4 and the sensor 5 do not obstruct one another. When the plane of an image formed by the photographing lens 2 is between the film surface 4 and the lens, namely at the front focus, the contrast output of the sensor 3 is greater than that of the sensor 5. On the contrary, when the plane of an image formed by the lens 2 is behind the film surface 4 at the rear focus, the contrast output of the sensor 5 is greater than that of the sensor 3. When the image is formed on the film surface, the contrast output of the sensor 3 is equal to that of the sensor 5.

This will become more apparent from the graphical representation of Figure 5. When the result obtained by subtracting the contrast output of the sensor 3 from the contrast output of the sensor 5 is positive in sign, rear focus is indicated. If the result is negative in sign, front focus is indicated. When the two contrast output are equal to each other, then proper focus has been achieved.

An embodiment of a single-lens reflex camera incorporating a focus detecting device according to the invention is shown in Figure 4. Light passing through a photographing lens 2 is divided into two parts by a half-transparency mirror 6. One of the two parts is directed upwardly by the half-transparency mirror and passes through a focusing surface 8, a condenser lens 9, a penta-prism 10 and a magnifier 11 to an eye 12 of the user. The other part is reflected downwardly by a second mirror 7, entering an optical system including glass blocks 13, 14 and 15. The light in the optical system is divided into two parts by a half-transparency mirror 16. One of the two parts advances straightly to a sensor 3 while the other is reflected by the half-transparency mirror 16 and a mirror 17 to a second sensor 5. The optical distance of the sensor 3 from the photographing lens 2 is different from the optical distance of the sensor 5 from the lens 2 and the difference between the two optical distances is 2A as shown in Figure 3. The optical distance is equal to a value which is obtained by dividing the distance between the sensors 3 and 5 by the refractive index of the glass block β if the inclination angles of the mirrors 16 and 17 with respect to the optical axis are 45°.

A plane whose optical distance from the photographing lens 2 is equal to the distance between the film surface 4 and the lens 2 will be referred to as "a film equivalent plane". The film equivalent plane is at the middle point between the sensors 3 and 5.

Figure 10 is an enlarged view showing the sensors and the glass blocks in more detail. In Figure 10, reference numeral 18 designates a substrate supporting the sensors 3 and 5 and reference numeral 27 designates a light shielding plate to block unwanted light. Figure 11 is a perspective view of the glass blocks 13, 14 and 15 and the sensors 3 and 5 the direction of arrangement of the sensors and the disposition of the mirror 17 and the half-transparency mirror 16.

Figure 6 is a circuit diagram showing a first example of a processing circuit for processing the outputs of the sensors. The operation of the processing cir cuit which is carried out until a difference output between contrast outputs is obtained from the outputs of the sensors will be described. In the circuit shown in Figure 6, each of the sensors 3 and 5 has five light receiving elements which are uniform in their photo-electric characteristics. The outputs of two adjacent light receiving elements are compared by a circuit 19 so as to determine the absolute value of the difference between the outputs. The absolute values thus obtained are summed in addition circuit 20 whereby a contrast output is provided.

An example of the circuit 19 provided for determining the absolute value of the difference between the outputs as shown in Figure 7. This circuit includes an operational amplifier OP_1 for determining the difference between the two signals supplied through two resistors R_6 and a circuit including operational amplifiers OP_2 and OP_3, diodes D_1 and D_2 and resistors R_1 to R_5. One example of the adder circuit 20 is shown in Figure 8.

Referring back to Figure 6, the contrast outputs of the sensors 3 and 5 are obtained with the circuits 19 and 20. The two contrast outputs have characteristic curves as indicated in Figure 5. The difference between the two contrast outputs is determined by a differential amplifier 21 as a result of which a front focus signal, focus signal or rear focus signal is provided.

The focus detecting device embodying the invention in which two arrays of sensors are used to detect front focus, focus and rear focus, unlike a conventional focus detecting device in which a single sensor is used and variations of the contrast output are detected by extending the photographing lens, is free from defocus which is attributed to movement of the image on the sensor which may result from shaking the camera. In addition, the device embodying the invention is free from difficulties such as those found in a system as disclosed in Japanese Laid-Open Patent Application No. 79531/1978 such as shaking of a camera and the corresponding lowering of characteristics due to a time delay required for switching two parts of a single line sensor, the necessity of miniturizing the optical system, and problems in increasing the size of the image pickup element.

Although two arrays of sensors 3 and 5 are employed, the sensors 3 and 5 can be formed on the same substrate. Furthermore the three glass blocks and the mirror 17 and the half-transparency mirror 16 interposed therebetween can be formed as a single glass plate. Therefore, integrated circuit techniques, which have reached a high state of development can be effectively applied to the device according to the invention. That is, the arrays of light receiving elements, the processing circuit and the optical arrangement can be formed as a single unit which can be incorporated in a panel as if it were a single sensor. If a silicon wafer is employed as the substrate 18 in Figure 11, then the sensors 3 and 5 and the signal processing circuit shown in Figure 6 can be formed on the wafer. In practice, the distance

between the sensors 3 and 5 is from one to several millimeters. Therefore, the thickness of the glass block assembly will typically be on the order of 1 mm in the direction of the optical axis. Accordingly, the entire glass block assembly of a device of the invention occupies substantially the same space as the cover glass of an ordinary line sensor.

Figure 13 is a perspective view showing an example of a device of the invention formed in a flat package utilizing integrated circuit techniques. The device includes a light shielding plate 27 for preventing light from entering the inside of the device with the plate 27 having an opening 48 for allowing light to be applied to the glass block 13, input and output pins 49 of the processing circuit made in the form of an integrated circuit, and a package 30 made, for instance, of ceramic.

In Figure 13, the sides of the glass block assembly are exposed so that the arrangement of the glass blocks 13, 14 and 15, and half-transparency mirror 16 and the mirror 17 can be readily understood. However, it is preferable that the sides be coated with light shielding material. It can be understood from Figure 13 that the size of the device is small enough to be mounted in a camera.

Since the front focus signal, the focus signal and the rear focus signal are provided with a device embodying the invention, an automatic focus adjustment device can be readily manufactured using such a device. A self-scanning type image sensor can be employed as the aforementioned sensor. Examples of the self-scanning type image sensor are one using an analog charge transfer element such as a CCD or a BBD and an MOS shift registor type element.

Figure 9 is a circuit diagram showing a first example of a signal processing circuit employing the analog charge transfer element. The outputs of the arrays of light receiving elements 3 and 5 are simultaneously transferred through transfer gates 25 to analog shift registers 24 where they are successively shifted to the right (as viewed in the figure) by transferring clock pulses produced by a clock pulse generator 26. The number of stages in the analog shift register 24 is larger by one bit than the number of light receiving elements. The analog shift register 24 includes taps so that the signal of the last stage and the signal of the stage immediately before the last stage can be outputted at the same time. In this manner, the outputs of adjacent light receiving elements are simultaneously applied to a comparison circuit 19. The comparison circuit 19 is similar to the circuit shown in Figure 7. That is, it is arranged to provide the absolute value of the difference between the two outputs of adjacent light receiving elements. The difference absolute value signal which is outputted by the comparison circuit 19 is integrated to form a contrast signal by an integration circuit 28. It should be noted that, in this case, the contrast output is in the form of a voltage.

An example of the integration circuit 28, as shown in Figure 12, includes a resistor R_{10}, an operational amplifier OP_5, a capacitor C, and a transfer gate TG adapted to integrate the difference absolute value signals for one scanning period.

Referring back to Figure 9, reference numeral 23 designates a reset circuit for the integration circuit 28. The reset circuit 23 operates to reset the contrast output each scanning period. Connected to the reset circuit 23 is a drive circuit for the transfer gates 25. Two contrast outputs provided through the integration circuits 28 are compared by a differential amplifier 21 whereby, similarly to the above-described case, one of the front focus signal, the focus signal and the rear focus signal is provided. More specifically, when the contrast output of the sensor 5 is greater than that of the sensor 3, a positive signal is outputted, when the two contrast outputs are equal, a zero signal is provided, and when the contrast output of the sensor 5 is smaller than that of the sensor 3, a negative signal is provided. That is, when the point of focus has been reached, the zero signal is outputted, the positive signal is outputted for front focus and the negative signal is provided for rear focus.

With a self-scanning image sensor, the output signal may become saturated or the output signal may become so small that it is buried in noise. This difficulty can be eliminated by the provision of another example of the focus detecting device according to the invention which will be described with reference to Figure 14. Glass blocks 13, 14 and 15 and sensors 3 and 5 employed in the example are substantially similar to those shown in Figures 10 and 11. However, it should be noted that light receiving elements M_1 and M_2 are additionally provided adjacent to the sensors 3 and 5 so that they receive light from the photographing lens which has passed through the half-transparency mirror 16 and light reflected by the mirror 17, respectively. The processing circuit shown in Figure 9 can be employed for processing the outputs of these light receiving elements. However, the clock pulse generator 26 would then operate to generate clock pulses having frequencies proportional to the outputs of the light receiving elements M_1 and M_2.

Light applied to the sensors 3 and 5 may be different in intensity from light applied to the light receiving elements M_1 and M_2. However, in practice, the difference in intensity can be neglected with the device according to the invention. In Figure 14, the sensors 3 and 5 observe the same object to be photographed although the optical distance of the sensor 3 from the photographing lens is different from that of the sensor 5 and light on the left of the sensor 3 is applied to the light receiving element M_1 while light on the right of the sensor 5 is applied to the light receiving element M_2. Thus, the light receiving elements M_1 and M_2 detect the quantities of light on both adjacent sides of the object which is observed by the sensors 3 and 5.

In the above example of the device thus constructed, the quantities of light on both sides of the sensors 3 and 5 are metered by the light receiving elements M_1 and M_2 to estimate the quantities of light on the sensors 3 and 5 so that the scanning rate of the sensors may be changed to control the photosensitivities of the sensors 3 and 5. Thus, the focus detecting device according to the invention is suitable for use with a variety of objects which are different in brightness.

The other embodiments of focus detecting devices for cameras will be described. In the case where the plane of the image is very far from the sensor, for instance a position indicated by B in Figure 5, the contrast outputs vary extremely slowly and, accordingly, the difference between the two contrast outputs is very small. Therefore, if the contrast signals contain significant amounts of noise, it is impossible to accurately compare the contrast signals. That is, the difference between the outputs of the sensors 3 and 5 may be zero not only when the lens is correctly focused on the object but also when the lens is greatly defocused.

In order to distinguish the two cases from each other in order to detect the correct focus point, the following conditions should be employed. Namely, it should be determined that two contrast outputs are higher than a predetermined level and that the contrast output of the sensor 5 is equal to that of the sensor 3. The case where the lens is greatly defocused can be detected from the fact that a low contrast output is present. The predetermined level is indicated as line D in Figure 5. A focusing signal representative of the fact that the lens is focused on an object may be outputted when the sum of the two contrast outputs is higher than a predetermined level and the output of the sensor 5 is equal to that of the sensor 3. In this case, the contrast outputs of the sensors are as indicated in Figure 15. As is clear from Figure 15, a level indicated by E is higher than the corresponding level in Figure 5. Therefore the probability of erroneous determination of the correct focus point as caused by noise is reduced accordingly.

Figure 16 is a circuit diagram showing a second example of a processing circuit employed in a focus detecting device according to the invention. The operation of the processing circuit, in which a focus signal is produced from the output signals from the sensors will next be described. In Figure 16, the circuit components that are common to those of Figure 6 bear the same reference numerals and operate in the same manner. The difference signal produced by the differential amplifier 21 is applied to a window comparator 29 whose example is shown in Figure 17. The comparator 29 operates to determine whether or not the difference between the contrast outputs of the sensors 3 and 5 can be regarded as zero with noise taken into account. If in fact the difference can be regarded as zero the circuit 29 outputs a high logic level or "H" signal. A comparator 30 operates to determine the contrast output of the sensor 5 is higher than the predetermined level. Since the contrast signal is a voltage, the voltage is compared with the constant voltage of a voltage source 31. When the contrast signal is higher than the constant voltage, the comparator 30 outputs an "H" signal. The outputs of the circuits 29 and 30 are applied to an AND circuit 32. When both of the outputs are "H" levels, the AND circuit 32 produces an "H" output which indicates correct focus.

The difference between the contrast outputs of the sensors 3 and 5 is outputted by the circuit 21 as described above. When the output is positive, the lens is focused behind the object (rear focus) and when it is negative, the lens is focused in front of the object (front focus).

A third example of the processing circuit is shown in Figure 18 in which an addition circuit 36 is further provided so that the sum of two contrast outputs is applied to the comparator 30. In this case, the reference or comparison voltage can be set high as described before so that the focus detection operation is very little affected by noise. A self-scanning type image sensor may be employed as the sensor in the processing circuit of Figure 18. The processing circuit may be equal in construction to that shown in Figure 9.

Another embodiment of a focus detecting device according to the invention will be described in which three sensors are employed. Figure 19 is a diagram for a description of the principles of operation of this embodiment. The three sensors 3, 5 and 40 are disposed as shown in Figure 19. The positions of the sensors 3 and 5 are the same as those shown in Figure 3. However, the additional sensor 40 is spaced by a distance F from the sensor 5 on the same side of the film surface 4.

Figure 20 indicates the contrast outputs of the sensors 3, 5 and 40 which result as the photographing lens is moved. In Figure 20, reference characters 3a, 5a and 40a designate the contrast outputs of the sensors 3, 5 and 40, respectively.

When the plane of an image is very far from the sensors as indicated by B in Figure 20 similar to the case where two sensors 3 and 5 are employed, the contrast outputs vary quite slowly with respect to the lens position. Accordingly, in this case, the difference between the contrast outputs 3a and 5a is very small. Therefore, if noise is present in the contrast signals, it is impossible to accurately compare the contrast outputs.

In order to make it possible to accurately compare the contrast outputs 3a, 5a and 40a, the amount of defocus must be smaller than a certain range. If this range is represented by G, then the range of defocus in which the contrast outputs 3a and 5a can be accurately compared is $G + A + A + G = 2G + 2A$. Sometimes a single-lens reflex camera is provided with a photographing lens having a large diameter and a long extension distance l from closest focus position to infinite focus position such as for instance 15 or 16 mm. In the case where an object having fine patterns is observed through such a lens, the contrast with respect to the amount of defocus is very low and the value G mentioned above is small. Therefore, it is impossible to cover the entire extension distance of the lens with the range of defocus $2A + 2G$.

In order to eliminate this difficulty, the sensor 40 is provided. That is, the provision of the sensor 40 incrreases the extension distance of the lens by F. The extension distance is 2G at the maximum. Therefore, the range of defocus in which the signals can be compared is increased to $2A + 4G$ at the maximum. If the range of defocus $A + F + G$ is larger than the extension distance l of the lens, for instance in the case of l as shown in Figure 20, a defocus direction detection signal for front focus or rear focus display and lens extension direction indiction

can be produced by the provision of a suitable circuit even when the photographing lens is maximumly defocused. When a close object is observed with the photographing lens set for infinite distance, then the plane of the image will be at the position J in Figure 20. In this case, the output of the sensor 40 is greater than that of the sensor 3 from which it can be determined that the lens is rear focused. On the contrary, when an object at infinite distance is observed with the photographing lens set for a close object, the differences between the sensors 3, 5 and 40 are typically not greater than the noise. In the case of rear focus, the output of the sensor 3 is smaller than that of the sensor 5 or 40 from which fact it can be determined that the lens is front focused. The width F cannot be increased to more than 2G. Therefore, for a photographing lens having a larger diameter and a longer extension distance, an additional sensor similar to the sensor 40 should be provided in order to increase the range of detection.

Figure 21 is a sectonal view showing an arrangement of three sensors and a glass block assembly provided therefor while Figure 22 is a perspective view of the same. The sensors 3, 5 and 40 are disposed at different optical distances from the photographing lens 2. The difference between the optical distances of the sensors 3 and 5 corresponds to 2A in Figure 20 and to K in Figure 21. The optical distance between the sensors 3 and 5 is $2A = K/n$, where n is the refractive index of the glass block 13. The difference between the optical distances of the sensors 5 and 40 corresponds to F in Figure 20 and to L in Figure 21. The optical distance between the sensors 5 and 40 is $F = L/n$. The sensors 3 and 5 are disposed on both sides of the film surface and spaced by the distance A therefrom. In Figure 21, reference numeral 27 designates a light shielding plate to block unwanted light.

In Figure 22, the glass block assembly is separated from the sensors in order that the construction and arrangement thereof can be clearly seen. However, in practice, they are disposed adjacent to each other.

Figure 23 shows a second example of a unit including glass blocks and three sensors. In this example, two layers of glass block assemblies are employed to reduce the distance between the sensors. Light directed along the optical axis 1 is divided into two parts of a half-transparency mirror 16. One of the two parts, the light passing through the half-transparency mirror, is applied to the sensor 3. The other part is reflected by a mirror 43 and is then divided into two parts by a half-transparency mirror 17. The light passing through the half-transparency mirror 17 is applied to the sensor 5 and the light reflected by the half-transparency mirror 17 is reflected again by a mirror 41 to the sensor 40. In this example, the distance between the sensors can be reduced and therefore the manufacturing cost of the arrays of light receiving elements can accordingly be decreased.

Figure 24 is a perspective view of an arrangement of a plurality of sensors and a glass block assembly. In this case, the numbers of sensors provided is four. That is, Figure 24 illustrates the general case in which a number of sensors which are arranged parallel to one another at intervals less than 2G in Figure 20.

A fourth example of the processing circuit is as shown in Figure 25. The operation of the processing circuit in which three focusing signals, namely those indicating front focus, rear focus and correct focus signals are obtained from the outputs of the sensors will be described. In this example, each of the sensors 3, 5 and 40 is made up of six light receiving elements which have uniform photoelectric characteristics. The outputs of two adjacent light receiving elements are compared with each other in a circuit 19 so that the absolute value of the difference between the outputs is obtained. The absolute values outputted by the circuits 19 are summed in a circuit 20 whereby the contrast output of the respective sensor is provided.

In this fashion, the contrast outputs 3a, 5a and 40a of the sensors 3, 5 and 40 are provided by the respective circuits 20. As described above, when 3a < 5a or 3a < 40a, the lens is focused behind the object and, when 3a = 5a and 3a or 5a is positive, the lens is correctly focused on the object. In the remaining case, the lens is focused in front of the object. In order to make this decision, the contrast output 3a is compared with the contrast output 5a in a differential amplifier 21. The window comparator 29, shown in detail in Figure 17, determines with the noise or the like taken into account whether the difference between the two outputs 3a and 5a is zero. If the difference is in fact zero, the output of the circuit 29 is raised to "H". A comparator 30 determines whether or not the output 5a is positive. When the output 5a is positive, the output of the comparator 30 is set to "H". The outputs of the two comparators 29 and 30 are applied to an AND gate 32. When the two outputs are at "H", the AND gate 32 outputs an "H" signal which is a focus signal. When the photographing lens is not correctly focused on the object, the output of the AND circuit 32 is at "L".

Next, the operation of the defocus direction detection circuit will be described. The contrast outputs 3a and 5a are compared in a comparator 44. When the contrast output 5a is greater than the contrast output 3a, the comparator 44 outputs an "H" signal. In this connection, the contrast output 5a may become greater than the contrast output 3a because of the presence of noise in a region such as that indicated by B in Figure 20. In order to eliminate this problem, an analog adder circuit 45 is used to elevate the signal 3a to 3' indicated by the dotted line in Figure 20. However, for rear focus the signal 3' due to the elevation increment should not be greater than the contrast outputs 5a and 40a in the range I.

In order to prevent erroneous signals due to the noise, the contrast output 3a is compared with the contrast output 5a in the comparator 44. When the contrast output 5a is greater than the contrast output 3a, the comparator 44 produces the "H" signal. The contrast output 3' is compared with the contrast output 40a in a comparator 46. When the contrast output 40a is greater, the comparator 46 produces an "H" output. The outputs of the comparators 44 and 46 are applied to an OR circuit 47. When the output of the comparator 44 or 46 is at the "H" level, the OR

circuit 47 produces an "H" output. Thus, at the point of correct focus, the output of the AND circuit 32 is at "H", at the point of front focus the output of the OR circuit 47 is at "L", and at the point of rear focus the output of the OR circuit 47 is at "H".

In the case that two sensors are provided, one to several millimeters is sufficient for the distance between the two sensors. Therefore the required thickness of the glass block assembly will be on the order of 1 mm in the direction of the optical axis. Similarly, for three sensors, the thickness of the glass block assembly may be less than 2 mm. Accordingly, it can be placed in a space which is substantially equal to the space occupied by the cover glass of an ordinary line sensor.

Furthermore, if three sensors are employed, the device may be formed as a flat package utilizing IC techniques. Similar to the first example, a self-scanning type image sensor may be employed as the sensor.

A second example of a processing circuit using self scanning type image sensors employing analog charge transfer elements (CCD or BBD) is shown in Figure 26. The operation thereof is substantially same as that of Figure 9, and the technique used for producing a defocus signal and a focus signal through comparison of the contrast outputs is similar to that described with reference to Figure 25. In Figure 26, reference character PD designates a photodiode which is used to modulate the clock speed.

As is clear from the above description, with the invention, in focus and defocus can be detected positively. Accordingly, the device according to the invention, unlike a conventional focus detecting device in which a single sensor is used and variation of the contrast output is detected by moving the photographing lens, is free from the difficulties in detecting the point of focus attributed to movement of the image of an object on the sensor such as may be caused by shaking the camera when the photographing lens is extended.

The device may be so arranged that the film surface does not lie between the sensors. When the plane of an image is at the midpoint between the sensors 3 and 5, the contrast output of the sensor 3 is equal to that of the sensor 5. However, with this arrangement, the device can be operated irrespective of whether or not the film surface is at the midpoint between the sensors 3 and 5. For instance, it is assumed that, when the film surface is moved by a particular value towards the rear focus side from the position "O" in Figure 5, the particular value is represented by Δx. Then, the contrast output of the sensor 3 is equal to that of the sensor 5 only at the point of front focus. Accordingly, if the value Δx is known, the focus position, which is the position at which the amount of out focus is zero, can be determined. Thus, even when the positions of the sensors 3 and 5 and the film surface are not defined, the focus position can be determined if the amount of shift of the film surface is known.

In the examples described above, although plural arrays of sensors are provided on both sides of the film surface, plural glass blocks assembled in the form of a sheet of glass plate, the mirror and the half-transparency mirror interposed between the glass blocks and the sensors formed on the substrate are assembled as a single unit. That is, the light receiving elements, the light receiving element arrays, the processing circuit and the optical system are assembled as one unit, as shown in Figures 4, 10, 11, 14 and Figures 21 to 24. Thus, a focus detecting device according to the invention can be incorporated in a panel as in the case of a single line sensor. Accordingly, utilizing integrated circuit techniques, the focus detecting device of the invention can be readily implemented. In the devices shown in Figure 10 for instance, a silicon wafer may be employed as the substrate 18 with the sensors and the signal processing circuit formed on the silicon wafer. In practice, it is sufficient that the sensors be spaced several millimeters from each other. In addition, the thickness of the glass block assembly may be reduced to less than several millimeters and, accordingly, the device can be incorporated in a space which is substantially equal to the space for the cover glass of an ordinary line sensor used in camera.

CLAIMS

1. A focus detecting device for a camera wherein the position of correct focus is automatically detected and the camera lens positioned accordingly comprising at least two groups of light receiving elements disposed in two parallel planes along an optical axis of a photographing lens of the camera with at least one of the planes lying on each side of a plane optically equivalent to a film surface; a circuit for analyzing outputs of the groups of light receiving elements for detecting the degree of focus in the planes in which the groups of light receiving elements lie and producing contrast outputs; and a processing circuit coupled to receive outputs from said analyzing circuit for producing a signal indicative of the lens being at a correct position of focus when the contrast outputs from a predetermined two of the groups of light receiving elements are equal to each other.

2. A device as claimed in claim 1 characterised in that each group of light receiving elements comprises a self-scanning array of image sensors.

3. A device as claimed in either claim 1 or 2 characterised in that said analyzing circuit comprises means for determining the absolute value of the difference between signals produced by adjacent elements and means for summing absolute value signals to provide a signal representing the sum of said difference for each groups of sensors.

4. A device as claimed in any one of the preceding Claims in which the analyzing means produces a signal indicative of the lens being at a correct position of focus only when the contrast outputs are higher than a predetermined level.

5. A focus detecting device for a camera substantially as hereinbefore described with reference to and as shown in the accompanying drawings.

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